CEREAL SMUTS

and their control

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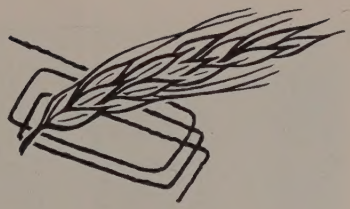
CEREAL SMUTS AND THEIR CONTROL



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The smuts of cereal crops cost the American farmers millions of dollars every year. The importance of cereals in the world food economy makes it highly desirable that growers recognize these smut diseases and try to control them. This bulletin describes the important cereal smuts in the United States and gives directions for their control.

THE SMUTS[1] OF WHEAT

Wheat in the United States is attacked by three smuts—bunt, or stinking smut; loose smut; and flag smut. The first two are widely distributed in all the wheat-growing areas of the United States. Flag smut now occurs only in limited areas in a few States.

STINKING SMUT, OR BUNT

Losses from stinking smut, or bunt, are of two kinds—field losses caused by reduction in yield and market losses caused by the reduction in the price paid for smutty wheat because of its discoloration and foul odor. Occasional smut explosions also cause losses, which may occur during threshing or while handling smutty seed in elevators. The oily nature of the smut spores makes them extremely combustible and, when carried in the air as a dust, they form an explosive mixture, easily ignited by sparks from belts or machinery. The total annual loss from bunt in the United States in recent years is estimated at about 20 million dollars. Much of this loss can be prevented.

Description

Two kinds of bunt occur on wheat in the United States—common bunt and dwarf bunt. Common bunt is more prevalent and better known than dwarf bunt. It stunts plants a few inches to as much as half the height of healthy plants, depending upon which of the two common bunt fungi is involved. Plants infected with dwarf bunt are from one-fourth to one-half the height of healthy plants. Symptoms of bunt usually are not apparent until heading time.

At the time of emergence from the boot smutted wheat heads are bluish-green in contrast to the yellowish-green color of healthy heads, and they contain smutted kernels, or smut balls, in place of normal kernels. These smut balls resemble normal kernels but are shorter and thicker and cause the glumes to spread apart. Each smut ball contains a mass of sooty, black powder, the individual particles of which are the spores, or "seeds," that per-

[1] Scientific names of causal organisms are listed on p. 28.

Figure 1.—*A*, Sound head of bearded wheat; *B*, a bunted head.

petuate the smut fungus (figs. 1, 2, and 3). The smut has a distinctive fishy odor. When the wheat is threshed, these smut balls are broken and the spores are spread over the seed and also blown to fields where they may infect winter wheat sown later in the fall.

Soil-borne spores of common bunt remain infective, however, only in areas like the Pacific Northwest where the soil remains dry from threshing until after seeding. Spores of dwarf bunt, however, may remain viable in the soil for several years. Following seeding, as the young wheat sprout grows from the seed to the surface of the soil, spores on the seed or in the soil develop slender infection threads that enter the seedling. As the plant grows, the smut fungus grows within it, finally producing smut spores in the young heads.

Conditions Influencing Bunt Development

Bunt fungi infect wheat more readily when the soil is fairly cool (45° to 55° F.) after sowing, and when the moisture content of the soil is from 15 to 60 percent of its water-holding capacity. Excessive soil moisture and high temperatures hasten germination of the wheat seeds and emergence of the seedlings, but retard germination of the smut spores and shorten the period during which they can cause infection. However, a continuous high temperature is unfavorable for the best development of the wheat seedlings, while at the same time it favors the development of certain other diseases and also infestation by hessian fly. It is not advisable, therefore, to sow winter wheat early in order to avoid bunt infection.

Infection by bunt is favored by soils rich in humus, and it is inhibited somewhat in heavy clay, peat, and highly acid soils. Potassium and phosphate fertilizers seem to stimulate bunt infection, while

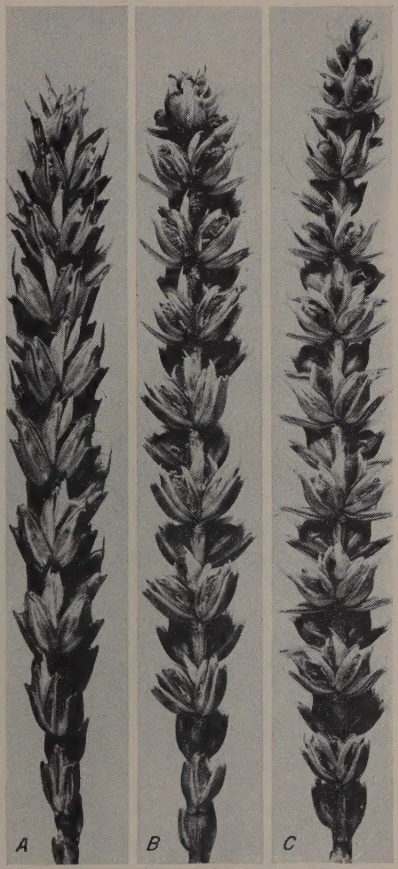

Figure 2.—*A*, Sound head of beardless wheat; *B* and *C*, bunted heads.

lime, nitrogen fertilizers, superphosphate, and calcium cyanamide repress it. These factors may account for the differences in infection observed at times in different fields of wheat grown from the same lot of seed.

Control

The most effective methods of controlling bunt are (1) the use of smut-free seed or of well-cleaned and treated seed from which the smut balls have been separated and (2) the use of varieties immune from or highly resistant to the disease.

Figure 3.—Bunt in wheat. *A*, *Tilletia caries* in Kanred wheat: *a*, Sound wheat kernels; *b*, bunt balls; *c*, bunt spores. *B*, *Tilletia foetida* in Harvest Queen wheat: *a*, Sound wheat kernels; *b*, bunt balls; *c*, bunt spores.

Cleaning and Treating the Seed

Seed wheat should be well cleaned to remove weed seeds, light shriveled kernels, and other impurities as well as any smut balls that may be present. It is best to select seed wheat that is as free from bunt as possible. Very smutty wheat should not be used for seed, because of the difficulty of removing all the smut balls and of killing all the spores on the seed.

In regions where soil infestation does not occur, bunt can be readily controlled by seed treatment. A number of satisfactory seed treatments for the control of bunt have been developed in recent years. These materials and the equipment and methods for applying them are discussed on pages 20 to 27. Treatments 1, 2, 3, 4, 5, 6, 7, 11, 12, 13, and 14 are suitable for controlling bunt.

Resistant Varieties

The use of resistant wheat varieties is the only satisfactory control for bunt known at present where soil infestation occurs. But varieties that are resistant to bunt in one area may be susceptible when grown in other areas because of different races or strains of the bunt organism present there. Varieties of wheat are being developed that, it is hoped, will resist all of the important races of the bunt fungi. Until this is done it is advisable to treat the seed of the supposedly resistant varieties. The treatment may prevent the increase of some virulent race or races of the bunt fungi that in the beginning may be present in very small quantities but which may increase from year to year until they cause heavy losses.

In recent years dwarf bunt has been increasing in prevalence and severity in certain areas in the Pacific Northwest. Its control by seed treatment is made impossible by the persistence of spores in the soil for several years, even in the absence of a wheat crop. The infected plants are so dwarfed that smutted heads are passed over by the harvesting machinery. As a result, the soil receives a tremendous amount of inoculum, as nearly all of the smutted heads are returned to the soil.

Bunt control is difficult under such severe conditions. Some measure of control has been obtained experimentally by applying hexachlorobenzene (treatment 4) or pentachloronitrobenzene (treatment 5) to the soil with the seed in the drill furrow at the rate of 100 pounds or more per acre.

LOOSE SMUT

Loose smut is prevalent especially in the humid and subhumid wheat-producing areas of the country. Losses from loose smut of wheat range from 3 to 18 million bushels a year, averaging about 7½ million bushels.

The disease is especially obnoxious when it appears in fields of wheat that are expected to produce certified seed. In most States a relatively small percentage of wheat heads infected with loose smut will bar a field from being certified.

Description

Loose smut of wheat, sometimes called black smut or black head, is distinctly different from stinking smut, or bunt. The diseased heads, unlike bunt, bear little resemblance to sound heads, because the entire head, except the central axis, is replaced by a black sooty mass of spores (fig. 4). These spores, which appear about the time the healthy heads are in bloom (fig. 5), may be carried for long distances by wind, insects, or other agencies. Many of the spores lodge in the normal wheat flowers. Here they germinate and develop long slender infection threads that, under favor-

Figure 4.—Loose smut of wheat: *A*, Infected head; and *B*, healthy head at same stage of bloom.

able conditions, grow into the developing embryo of the young wheat kernels that are forming inside the chaff. When these infected kernels are mature, they cannot be distinguished from smut-free kernels. However, if such kernels are used for seed without being properly treated with hot water (see below), the smut fungus inside each seed starts to grow when the seed germinates and sends infection threads upward into the plant. When the head forms, a mass of black spores appears in place of the kernels. Infection by loose smut takes place only through the wheat flowers. Spores on the seed or in the soil will not infect the seedlings, as do spores of stinking smut.

Control

Hot-Water Treatment

Chemical seed disinfectants that control stinking smut of wheat will not control loose smut. Hot-water seed treatment is effective, however. It is applied as follows: The seed is first put in loosely woven burlap sacks. These should be only half-filled and tied at the top. The seed is then soaked in unheated water for 6 hours or longer. (Hard seed wheat requires a longer presoak than soft wheat.)

During this period the sacks should lie on their sides and should be turned or rolled occasionally to prevent caking of the swelling seed. The presoaked seed is dipped in water at about 120° F. for a few minutes and then immersed for 10 minutes in water held at 130°. The sacks should lie on their sides also during the 10-minute treatment and should be moved about to insure an even penetration of the heat. Immediately after treatment, the seed should be raked out in a thin layer to cool and dry. It is safer to sow the seed after it has been thoroughly dried, but it will run through the drill as soon as it is surface dry. When such seed is sown, the drill should be set at a higher seeding rate to allow for the swollen condition of the grain. Seed that is only

Figure 5.—Loose smut of wheat: Infected heads after smut spores have been scattered and sound heads have begun to fill.

surface dry contains enough moisture to germinate, and the stand may be severely reduced if such seed is sown in dry soil.

The hot-water treatment is not recommended for treating seed for the entire crop. It is difficult to apply and may reduce seed germination, particularly when the seedcoats have been broken, as in threshing. If seed from smut-free fields cannot be obtained, it is best to treat only a sufficient quantity for sowing a seed plot that is isolated from fields sown to untreated wheat. This crop and successive crops, if properly isolated, may remain relatively free from loose smut, so that further seed treatment may not be necessary for several years. However, infection of the seed may take place if loose smut is present in nearby fields.

Community seed-treating plants for applying the modified hot-water treatment have been operated satisfactorily in several States. Usually the plants are managed by the county agricultural agent or by a group of farmers. A number of large, relatively smut-free areas have been established through the use of such treated seed and of seed from crops produced from the treated seed. The beneficial effects of the treatment are made more last-

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ing in this way, as the fields within the smut-free areas are mutually protected from infection.

Resistant Varieties

Wheat varieties differ widely in their resistance to loose smut. Many of the important varieties are susceptible. In view of the difficulty in controlling loose smut through seed treatment, control through selecting and breeding resistant varieties would seem the logical course. This problem, however, is complicated by the existence of at least 11 races of the loose smut fungus in the United States. Selections that are resistant to the races of smut in one area may be highly susceptible to races prevalent in other areas.

FLAG SMUT

Flag smut has long been prevalent in Australia, where it formerly was one of the most destructive diseases of wheat. Under some conditions this disease often destroys 10 percent of the crop there, and losses of one-half of the crop are not rare. Flag smut occurs also in China, Japan, India, South Africa, Italy, and Spain.

In the United States flag smut was discovered in Missouri in 1918. Later it was found in Illinois, Kansas, and in 1940 in Washington. Recent surveys indicate that the range of the disease is gradually increasing from these centers of infection. Although it has not become severe in any locality in this country, its persistence in certain major wheat-producing areas is a potential danger.

Description

Flag smut appears as long black stripes running lengthwise on the leaf blades and on the upper parts of the stems of the plants (fig. 6).

Infected plants usually have short or more or less dwarfed stalks that seldom produce heads. Usually the entire plant is affected, although partly infected plants are not uncommon in certain varieties. When infected leaves dry, they split

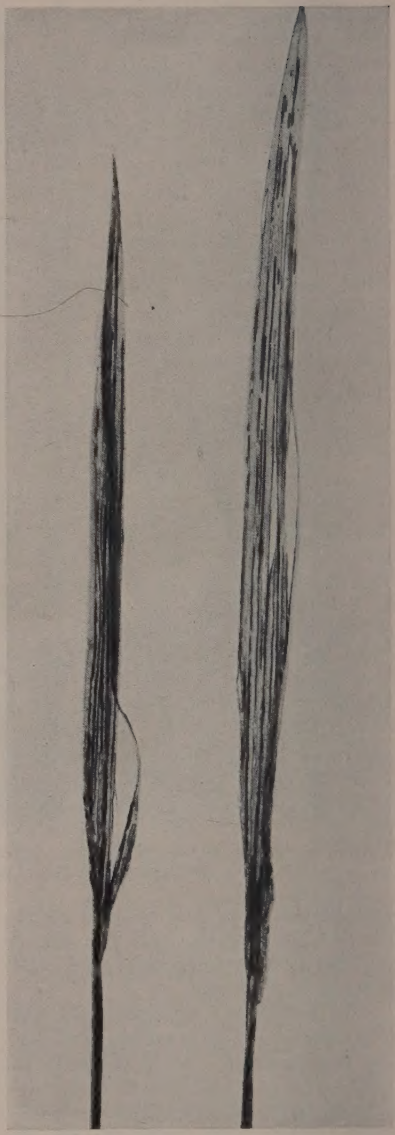

Figure 6.—Leaves and stems of wheat infected with flag smut.

along the black streaks and free the black powdery spores of the smut fungus. The spores are blown to nearby plants or fall to the ground where they may be spread by the feet of animals and man and by machinery. When infected wheat is being harvested or threshed, flag smut spores are carried to the sound wheat kernels from infected plants. This smut lives over in the soil, or, as with bunt, it may be carried on wheat seed. Infection of the young wheat seedlings takes place when the seed germinates. After entering the seedling, the fungus mycelium grows inside the stem and leaves of the plant. Infected plants can be detected early by the black streaks on the leaves before the jointing of the plant begins.

Control

Flag smut of wheat can be controlled by crop rotation, seed treatment, and the growing of resistant varieties.

As with bunt, seed treatment does not control flag smut in wheat grown in smut-infested soil. The flag smut spores in the soil usually do not survive when wheat is not grown on the land for one year. However, the soil may be reinfested by spores from nearby fields. Flag smut persists only in winter wheat areas where a mild winter climate prevails and continuous wheat culture is practiced. In general the treatments suitable for controlling bunt (see p. 5) will also prevent flag smut from seed-borne spores.

THE SMUTS OF RYE

Three smuts—bunt or stinking smut, loose smut, and stalk smut—attack rye.

STINKING SMUT AND LOOSE SMUT

Stinking smut and loose smut are caused by the same smut fungi that cause these diseases in wheat. Their occurrence in rye, however, is relatively rare, and hence they are of little economic importance. However, there is always the possibility that they may become important through the introduction of more highly susceptible varieties of rye or through the development of more virulent races of the smut organisms. In case this should occur, it is well to know that these diseases in rye can be controlled by the same treatments recommended for their control in wheat.

STALK SMUT

Stalk smut of rye is caused by a fungus closely related to the one causing flag smut of wheat, and the two diseases are similar in several respects. The rye smut, however, cannot attack wheat nor can the wheat smut attack rye.

The disease becomes evident just before the rye heads appear (fig. 7). Diseased plants are darker green than normal, and lead-colored streaks appear on the leaves and stems. The stems are usually twisted or distorted and finally may be split open by the fungus within, revealing masses of black spores. These spores are spread by the wind to contaminate the soil and the seed of healthy heads, as described for flag smut of wheat.

The control measures described for flag smut of wheat apply also to stalk smut of rye.

THE SMUTS OF BARLEY

Barley in the United States is attacked by three smuts—one species of covered smut and two species of loose smut (fig. 8). The loose smuts are similar in appearance but differ in their manner of infection. Covered smut is found in all areas where barley is grown, but the two loose smuts normally are confined to humid and subhumid areas.

Figure 7.—Heads and culms of rye infected with stalk smut.

COVERED SMUT

Annual field surveys have indicated that the average annual reduction in yield caused by covered smut approximates 2 million bushels. The use of resistant varieties and improved seed-treatment methods may have reduced these losses in recent years.

Description

Heads of barley infected by covered smut appear a little later than the healthy heads. The smutted heads may emerge completely or remain half-enclosed in the boot (fig. 8, *B*). At first the mass of smut spores is covered with a thin grayish membrane, but this soon splits and permits an early spread of spores and inoculation of the developing seed in healthy heads. This continues while the grain is in the field. The breaking up of smutted heads and the spread of spores to seed are completed with threshing. Spores often lodge beneath the glumes and under favorable conditions may germinate there and form a fungus growth on the surface of the pericarp, or seedcoat, beneath the glume. This makes it difficult to control the disease effectively with nonvolatile dust fungicides.

When infected barley seed is sown, the smut spores germinate at the same time that the seed germinates and the smut germ tube invades the young seedling before the seedling emerges from the soil. The smut infection strand, or mycelium, in the seedling invades the growing point of the plant and keeps pace with it until it is time for the kernels to form. The food materials provided by the plant to produce kernels are then used by the smut fungus to produce spores.

Infection of the seedlings by covered smut is favored by certain environmental conditions after seeding, such as a somewhat acid soil, deep sowing, medium moisture content of the soil, and soil temperatures between 50° and 70° F.

Control

Seed Treatment

Covered smut of barley is readily controlled by the use of certain chemical seed treatments. Nonvolatile contact fungicides, such as copper carbonate, generally are ineffective because the spores and mycelium underneath the glumes are not reached by these materials.

Figure 8.—*A*, Loose smut and *B*, covered smut of barley; *C*, healthy head of barley.

Volatile organic mercurials are effective if properly applied, as described on pages 22, 23, and 27. Treatments 1, 2, 3, 11, 12, and 14 are recommended for the control of covered smut.

Resistant Varieties

Losses owing to covered smut can be prevented largely by growing resistant varieties of barley. But varieties that are resistant in one region may be susceptible to the smut prevalent in other regions because there are 13 or more races of the covered smut fungus. Some varieties have shown a high degree of resistance to several races of covered smut and 2 varieties are resistant to all 13 races.

LOOSE SMUTS

Description

Two species of loose smut attack barley in the United States. These

are known as the nuda, or deep-infecting species, and the nigra, or shallow-infecting species. Heads smutted by these species are similar in appearance and resemble heads of wheat attacked by loose smut (fig. 8, *A*). Also like the wheat smut, the loose-smutted heads of barley emerge at the time the healthy heads emerge and the loosely held spores are blown about the field. Some of the spores get into the barley flowers that open in the process of blooming. At this point there is an important difference in the behavior of the two barley loose smuts.

Spores of the nuda species develop infection threads that grow into and within the tissue of the young, developing barley kernel. The manner of infection is like that described for the loose smut of wheat. Spores of the nigra smut, however, develop infection threads that are confined to the outer layers beneath the seed hulls.

When the seed is sown, the nuda smut resumes its growth within the plant, and eventually produces a mass of spores in the young heads shortly before they emerge from the boot. The spores of the nigra smut, following seeding, send infection threads into the seedling during its growth from the seed to the surface of the soil. These threads grow within the developing plant and eventually produce spores in the heads in place of kernels in a manner similar to that destribed for the nuda smut.

Control

Seed Treatment

Since the nigra loose smut is carried on the seed or under the seedcoat in the same manner as described for barley covered smut, the method of control also is the same. Treatments 1, 2, 3, 11, 12, and 14 have been found effective for controlling this smut.

The nuda loose smut, however, infects the embryo and can be controlled only by the hot-water or other long-soak seed treatment. The hot-water treatment is similar to that described for controlling loose smut of wheat, except that after the 6-hour presoak and the tempering bath at 120° F. the seed is immersed in water at 126° F. for 13 minutes, after which it is cooled and dried. A somewhat heavier rate of seeding is advisable because of a slight swelling of the seed and some injury to its viability.

Resistant Varieties

There are varieties of barley resistant to either the nigra or the nuda loose smut and some are resistant to both. However, when such varieties are grown in new localities where other races of these smuts exist, the seed may become infected and when subsequently sown it may produce smutted plants.

THE SMUTS OF OATS

Oat plants are subject to attack by two smuts—covered smut and loose smut. Annual field surveys over a period of years indicate that the average annual loss in yield caused by both oat smuts is less than 1 percent of the crop.

COVERED SMUT

Description

Covered smut is evident in the field for a longer period than loose smut, because the glumes of the smutted panicles are not completely destroyed (fig. 9, *C*). The smut mass, which replaces the kernel, is covered by a thin grayish membrane that usually does not rupture until harvest or threshing time. Its period of persistence varies with different oat varieties. At harvest and threshing time the spores are spread

Figure 9.—The oat smuts: *A*, Loose smut; *B*, healthy head; *C*, covered smut.

over the grain and some lodge beneath the glumes, where they germinate and spread a mat of fungus mycelium (threads) over the seed-coat. Other spores remain on the outer surface of the glumes.

When the seed is sown in moist soil at the right temperature (60° to 75° F.), these spores germinate with the seed and send infection threads, or mycelium, into the young seedling, where they invade and keep pace with the growing point of the plant. The mycelium under the glumes also invades the seedling and, under conditions unfavorable for infection, the mycelium is more likely to cause infection than the spores on the outside of the seed. When the head forms, a mass of spores replaces the kernels within the glumes.

Control

Since much of the infective material is beneath the glumes of the kernels, covered smut cannot be entirely prevented by nonvolatile materials such as copper carbonate. A volatile fungicide is necessary so that the fumes will reach the spores and mycelium beneath the glumes. Treatments 1, 2, 3, 11, 12, and 14, discussed on pages 22, 23, and 27, have been found effective. This disease is now largely prevented by growing resistant varieties. There is always the possibility, however, that new races may appear that can attack these varieties. Should this occur, seed treatment should be employed immediately to prevent the increase of these virulent races.

LOOSE SMUT

Description

Loose smut of oats is more conspicuous in the field than covered smut when it first emerges from the boot (fig. 9, *A*), because the smut is not hidden by the glumes or chaff. The smut mass of each spikelet may be surrounded at first by a delicate white membrane, but, unlike the covered smut membrane, this soon breaks and the black spores are carried by the wind to the flowers of healthy heads where they lodge mostly beneath the glumes. Here they germinate and spread a mat of fungus mycelium over the seedcoat under the hull. After the seed is sown, the fungus invades the young seedling before emergence and grows inside the plant until it finally invades the developing head and forms smut masses in place of the kernels.

Control

Loose smut of oats is not "embryo-infecting" like loose smut of wheat and the nuda loose smut of barley; therefore, it can be controlled by chemical seed treatments. It cannot be controlled completely by nonvolatile surface disinfectants, because of the spores and mycelium beneath the hull. The treatments recommended for control of covered smut (1, 2, 3, 11, 12, and 14) are suitable also for controlling loose smut.

Like covered smut, this smut is now largely prevented by growing only resistant varieties of oats. It is also possible, however, that new and more virulent forms of loose smut may appear, and seed treatment should be used to prevent their increase.

THE SMUTS OF SORGHUM

The term "sorghum" generally includes the different varieties of sweet sorghum or sorgo, the grain sorghums, broomcorn, and Sudan grass. These cereals are subject to a number of smut diseases, three of which are common in the United States. They are loose kernel smut, covered kernel smut, and head smut. Sorghum is attacked in rare instances also by a loose smut that attacks Johnson grass.

COVERED KERNEL SMUT

All of the above groups of sorghum are susceptible to covered kernel smut. This disease occurs wherever sorghum is grown and is one of the most destructive diseases of sorghum in the United States.

Description

Covered kernel smut does not stunt the plants, and therefore infected plants cannot be distinguished from noninfected plants until the heads appear. Cylindrical or conical smut galls are then found in the heads in place of sorghum kernels (fig. 10).

At first the smut galls are covered with a light-gray or brown mem-

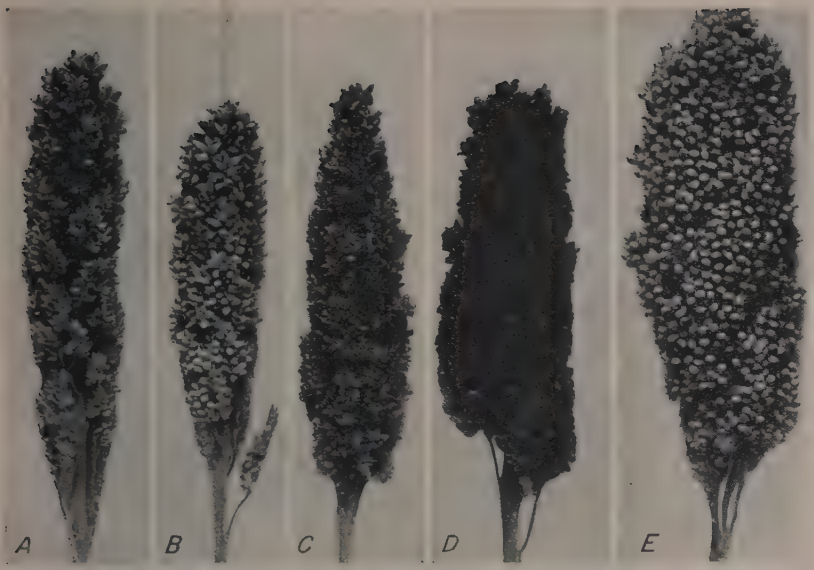

Figure 10.—Covered kernel smut of sorghum: *A*, Shortly after emergence; *B*, fully ripe; *C*, gall coverings ruptured; *D*, spores exposed and spreading; and *E*, healthy head of sorghum.

brane, or peridium. Later this membrane breaks, revealing the mass of dark spores underneath. Some of the spores are scattered in the field, but most of them remain in the galls until the sorghum is combined or threshed. This breaks up the smut galls and spreads the spores to the sound seeds.

When smutted seed is planted, the spores germinate with the seed. The smut fungus invades the young seedling and thereafter grows unobserved inside the plant. When the kernels begin to form, the smut fungus invades them and uses this food material to form smut galls in place of kernels.

Five different strains or races of covered smut are known in the United States. All five races are able to attack sorgo, kafir, durra, broomcorn, and Sudan grass. Milo and hegari are susceptible to race 2, while Gurno and common feterita are susceptible to race 3. Spur feterita is highly resistant to or immune from all races of covered kernel smut.

Control

Covered kernel smut can be controlled effectively by growing resistant varieties or by treating the seed with any one of a number of fungicides before planting. Varieties with persistent glumes should be treated with a volatile fungicide such as Ceresan M, Agrox, or Panogen that will kill the spores beneath the glumes. Seed without glumes can be treated effectively with nonvolatile fungicide such as treatments 6, 7, 8, 9, 10, and 13.

LOOSE KERNEL SMUT

Loose kernel smut is much less common than covered kernel smut. It is found only occasionally and mostly in the southern Great Plains. It attacks all groups of sorghum, but some varieties in certain groups are immune or highly resistant.

Description

The galls that are formed in place of the normal kernels (fig. 11, *B*) are long and pointed. They are covered by a thin membrane, which usually breaks soon after the galls reach full size. The dark-brown spores are soon blown away, leaving only a long dark curved structure in the center of what was the gall (fig. 11, *C*).

Many of the spores lodge on the seeds. When such seed is planted, the spores germinate at temperatures favorable for seed germination. The smut fungus invades the sorghum seedling before the seedling emerges from the soil and, as in covered kernel smut, continues to grow inside the plant. When the plants head, the long pointed smut galls appear in place of normal kernels.

Loose kernel smut, unlike covered kernel smut, stunts the infected plants and often causes the development of abundant side branches. Windborne spores of loose kernel smut may cause secondary infection in late heads on otherwise healthy plants.

There are at least two physiologic races of loose kernel smut. Some groups or varieties of sorghum are resistant to both races; some are susceptible to both; and some are resistant to one race and susceptible to the other.

Control

Loose kernel smut can be controlled by the same materials and methods suggested for the control of covered kernel smut.

HEAD SMUT

Head smut of sorghum is not common in the United States and causes relatively little damage. Occasionally individual fields have been damaged, but since it was first observed in 1890 total losses from head smut have been small.

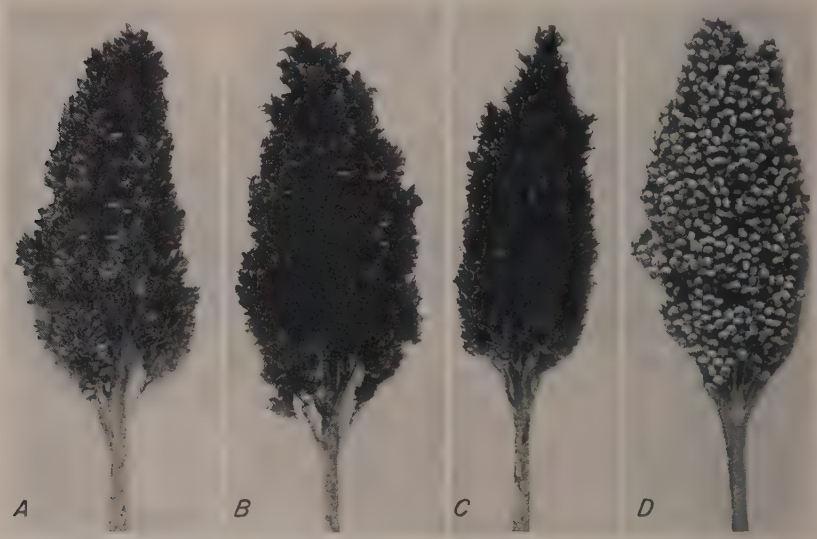

Figure 11.—Loose kernel smut of sorghum: *A*, Shortly after emergence; *B*, gall coverings ruptured; *C*, smut spores mostly scattered; and *D*, healthy head of sorghum.

Description

Head smut differs from the kernel smuts in that it destroys the entire head by transforming it into one large mass of dark-brown spores (fig. 12). The smut is first observed

Figure 12.—Head smut of sorghum.

at heading time, when a large smut gall covered with a whitish membrane bulges out of the boot. This membrane soon breaks, and the black smut spores are then scattered by the wind and rain to the soil and to plant refuse, where they overwinter.

Next spring and summer these spores germinate and produce smaller spores called sporidia, which infect the young sorghum plants. The fungus grows within the plant until the heading stage, when the smut gall appears in place of a normal head. Because head smut is largely soil-borne, plants grown from clean or treated seed may become infected. The disease may be introduced into previously noninfested fields if infested seed is planted. But infested seed is not essential for infection, as it is the spores in the soil that usually cause infection of the seedling.

Control

Sanitation and rotation are important control measures. Seed treatment with organic mercurials prevents spread of the disease to uninfested fields by seed-borne spores. The sweet sorghums, or sorgo, varieties are relatively susceptible, while varieties of feterita, kafir, milo, broomcorn, and kaoliang are resistant.

THE SMUTS OF CORN

Corn, or maize, is subject to attack by two smut diseases—common corn smut and head smut.

CORN SMUT

Corn smut is one of the most widely distributed corn diseases and occurs wherever corn is grown. At times it causes relatively heavy losses, especially in the warmer and somewhat drier corn-growing areas.

Description

The smut galls (fig. 13) may develop on any of the aboveground parts of the plant where young tissues are exposed. Infection takes place only in young succulent tissue, unless entrance is gained through wounds. Young leaf tissue is usually the first to be attacked. Next in order are tassels and ears. Stalks may be attacked through openings made by insects, implements, or

Figure 13.—Common corn smut.

other agencies. The galls formed are irregular in shape and may vary in size from one half to 6 inches in diameter. At first the smut gall is white in the interior, as it is composed of innumerable threads of fungus mycelium and some plant tissue. Later these closely packed threads break up into black spores (chlamydospores). The gall is covered with a white membrane until the spores are mature. Then the membrane breaks and the black spores are released and are spread by the wind to the soil and to decaying plant refuse, where they overwinter.

The following summer these spores produce smaller spores (sporidia), which are carried by air currents to the cornfields, to infect the next crop.

Unlike other grain smuts, corn smut is not seedborne and is not systemic; that is, the fungus does not invade the young seedling and develop unobserved inside the plant. Each smut gall is a separate local infection caused by spores carried to that part of the plant by air currents.

Control

Since corn smut is not seedborne, it cannot be controlled by seed treatment. Control measures are limited to sanitation, crop rotation, and the development and use of resistant corn hybrids. The removal and burning of the smut galls may be practicable where infection is not too severe. This will reduce the amount of inoculum present the next year. A heavy stand of grain or some forage crop following corn tends to prevent the spread of the sporidia from the soil to nearby cornfields.

HEAD SMUT

Head smut in corn is caused by the same fungus that produces this disease in sorghum, although each of these crops is attacked by a separate race that will not attack the other crop. In corn the fungus may attack the tassel or the ear (fig. 14), and it forms the same type of smut gall described for sorghum. All other statements made about this disease in sorghum (p. 17) apply also to head smut in corn.

THE SMUTS OF RICE

Rice in the United States is subject to attack by two smuts—kernel smut and leaf smut. Neither of these smuts is of major importance.

KERNEL SMUT

Kernel smut of rice is found occasionally in Arkansas, Louisiana, and Texas. It may reduce the yield somewhat and damage the quality of the grain because of the dark color the smut spores impart to the milled rice.

Figure 14.—Head smut of corn: *A*, Infected tassel; *B*, infected ear.

The smutted kernels are not readily observed until the rice is mature. Usually only a few smutted kernels are found in a head. Severely smutted kernels are light enough to float in water, but partly smutted kernels sink and cannot be separated from normal kernels by flotation in water.

Control

No definite control measures for this disease are known, as the exact manner of infection has not been determined. Attempts to produce the disease by using naturally infested or artificially inoculated seed have been generally unsuccessful. The disease apparently is prevented to a great extent by natural conditions in the field. Although the commercial varieties now grown seem to differ somewhat in susceptibility, definitely resistant varieties have not been developed.

LEAF SMUT

Leaf smut of rice occurs to a limited extent in Arkansas, Louisiana, and Texas. The smut appears late in the season as small black spots on leaves, leaf sheaths, and occasionally on the upper part of the stalk. These spots contain the black smut spores. This smut injures the plant somewhat by reducing the leaf area.

The disease is of minor importance, and the only known means of control is by the use of varieties that show a high degree of resistance.

CONTROL METHODS AND MATERIALS

The smuts of cereals, with a few exceptions, can be controlled by (1) the use of smut-free seed; (2) the use of well-cleaned and treated seed from which partly infected kernels, smut balls, and much of the free smut have been removed; or (3) the

use of varieties immune from or highly resistant to the smut in question.

CLEANING SEED

Good farm practice demands that seed should be cleaned whether or not it is smutty. Cleaning the seed removes much of the free smut, partly infected kernels, smut balls (especially in wheat), weed seeds, light shriveled kernels, and other impurities. It is best to use seed that is as free from smut as possible. Very smutty seed should not be used, because of the difficulty of killing all of the seed-borne inoculum and, in the case of wheat, removing all the bunt balls. Seed wheat should be run through the fanning mill several times until all the smut balls have been removed. The best results are obtained when the fanning mill is run at the recommended speed but at less than its rated capacity. In many sections of the country there are central seed-cleaning plants where, for a few cents per bushel, seed can be more thoroughly cleaned and the smut balls removed more effectively than is possible with the equipment found on the average farm. In a number of communities this work is being done very efficiently by means of portable outfits mounted on trucks.

SEED TREATMENTS FOR CEREAL SMUTS

With the exception of the corn and rice smuts and head smut of sorghum, all the cereal smuts, in the absence of soil infestation, can be prevented by some form of seed treatment.

There are at present four methods of treating seed: (1) The seed may be soaked in a fungicidal solution (or in hot water) for a definite period and then dried either by spreading it out in a thin layer or by means of a seed drier; (2) a weighed or measured amount of a dust fungicide may be added to a weighed or measured amount of seed and the two mixed thoroughly until the seed is evenly coated with the dust; (3) the desired amount of dust fungicide may be applied in the form of a souplike slurry in a special slurry treater, so that the seed absorbs less water than 1 percent of its weight and requires no drying; and (4) certain volatile liquid fungicides may be applied in concentrated form by the "short" or "quick" wet method in which a small measured amount of liquid is thoroughly mixed with a given amount of seed. These fungicides, which are necessarily volatile, can also be applied in a slurry treater if they are first diluted with the proper amount of water.

Liquid Treatments

Formaldehyde formerly was used extensively for treating seed of wheat, barley, oats, and sorghum. Its use is now generally discouraged, because better materials are available and, in addition, it often injures the seed and does not protect it against soil-borne fungi. However, if the better materials are not obtainable and the seed is smutty, formaldehyde may be used as follows: The seed should be thoroughly cleaned to remove free smut, smut balls, light kernels, weed seeds, and trash. For barley or wheat, mix 1 pint of commercial formaldehyde with 40 gallons of water. For oats or sorghum, use 1 pint of formaldehyde to 30 gallons of water. This should be enough to treat about 50 bushels. If the seed is free from smut balls and partly infected kernels, it may be placed in coarse sacks (half-filled), tied at the top, and immersed in the formaldehyde solution for at least 10 minutes. It is

then removed from the solution, allowed to drain, and spread out to dry. It should be sown not later than the next day. Enough seed is usually treated at one time to provide for one full day's seeding.

CAUTION

Formaldehyde is poisonous! Keep it out of the eyes and do not breathe the fumes. Treat seed in the open, or in a well-ventilated room.

If cleaning does not completely remove the smut balls from the seed, the treatment should be applied in open tubs so that they can be floated off. The seed is poured slowly into the solution and stirred at the same time. Most of the smut balls and trash will then come to the surface and can be skimmed off. After about 10 minutes the solution should be drained off through a screened hole at the bottom of the tub. If two such tubs are available the solution may be caught in the second tub, and another lot of seed can be soaking while the first lot is being drained and spread out to dry. All sacks should be free from smut to avoid recontamination of the seed.

Commercial seed treaters may be used for treating large quantities of seed. These are built so that they float out the smut balls and trash and wet the seed in a continuous operation.

Several precautions should be taken when formaldehyde solution is used: The solution should be of proper strength; the seed should be sown within 24 hours after being treated; the seedbed should be moist; and the rate of seeding should be increased by about one-fourth to compensate for the swollen kernels. Formaldehyde-treated seed sown in dry soil usually gives a very poor stand. When seed must be sown during a dry period the formaldehyde treatment should not be used.

Formaldehyde may be applied to oats and barley also by the sprinkle method. A pint of formaldehyde is mixed with 10 or more gallons of water, and this solution is sprinkled uniformly over 50 bushels of seed grain as it is being shoveled from one pile to another or spread out in a thin layer on a clean floor. The seed should be shoveled until it is uniformly moist and then covered with a disinfected canvas for at least 4 hours or overnight, after which it should be sown at once to avoid severe injury.

Oats may be treated also by mixing 1 pint of commercial formaldehyde with 1 pint of water, and spraying this amount on 50 bushels as it leaves the grain spout or as it is shoveled from one pile to another. It is then covered for about 4 to 8 hours, after which it is sown immediately. This is similar to the "short" or "quick" method used with some volatile mercurials.

It should be emphasized that formaldehyde is not recommended when better materials are available.

Dust and Slurry Treatments

Dust fungicides may be applied to small lots of seed by means of any one of a number of homemade treaters. Perhaps the best known are the barrel and the oil-drum treaters (figs. 15 and 16). The oil drum is the more durable, as the barrel treater may dry out and

CAUTION

All seed-treatment fungicides should be regarded as poisonous. Do not inhale the dusts or fumes. Treat seed in a well-ventilated place or outdoors. Wear an approved dust mask when applying dusts or when handling dusted or slurry-treated seed.

Avoid getting fungicides on the skin, as burns or blisters may result. Wash hands frequently and keep them dry. Do not use treated seed for food or feed.

Sacks or other containers that have been used for treated seed should be cleaned thoroughly before being used for other purposes.

cease to be dusttight. These treaters are suitable for applying all types of dust fungicides to seeds and will enable two men to treat 20 to 40 bushels per hour. The treater should not be more than half-filled to treat seed properly.

Treaters of the gravity type (fig. 17) are suitable only for applying volatile dusts, as they do not cover the seed so thoroughly as do the "batch" type of treaters. The capacity of the gravity types varies with their size and method of operation. Such treaters on the farm may handle only 30 to 60 bushels per hour, while large installations in commercial plants may treat several hundred bushels per hour.

Slurry treaters were introduced in 1946 and were designed to eliminate the dust nuisance encountered when applying dust fungicides to seed (fig. 18). The slurry is made by mixing 1 to 2 pounds of the dust fungicide per gallon of water. For example, 1 pound of fungicide in a gallon of water will treat 32 bushels of wheat, barley, or oats at the rate of one-half ounce per bushel and will add less than 1 percent of moisture to the seed. For heavier dosages a relatively greater amount of chemical per gallon is used.

Slurry treatments are applied best by means of one of the commercial slurry treaters now on the market. By means of these the rate of application is governed by the slurry concentration (pounds to the gallon); the size of the slurry bucket (usually 23 or 46 cc.); and the gate number, which governs the amount of seed receiving the slurry delivered by the slurry bucket. Directions for properly applying the various fungicides either as dusts or slurries usually are given on the fungicide containers.

Slurry treatments may be applied to small lots of seed also by means of one of the small rotary batch treaters that handle only 2 bushels or less at a time. The proper amount of slurry is added to a measured or weighed amount of seed in the treater, and the treater is then rotated about 30 times. The seed is then sacked and held for at least a day or two before sowing if a volatile material has been used.

The following materials (numbered from 1 to 10 for convenient reference) may be applied either as dusts or slurries:

1. Ceresan M (7.7 percent ethyl mercury *p*-toluene sulfonanilide) may be applied at one-half ounce per

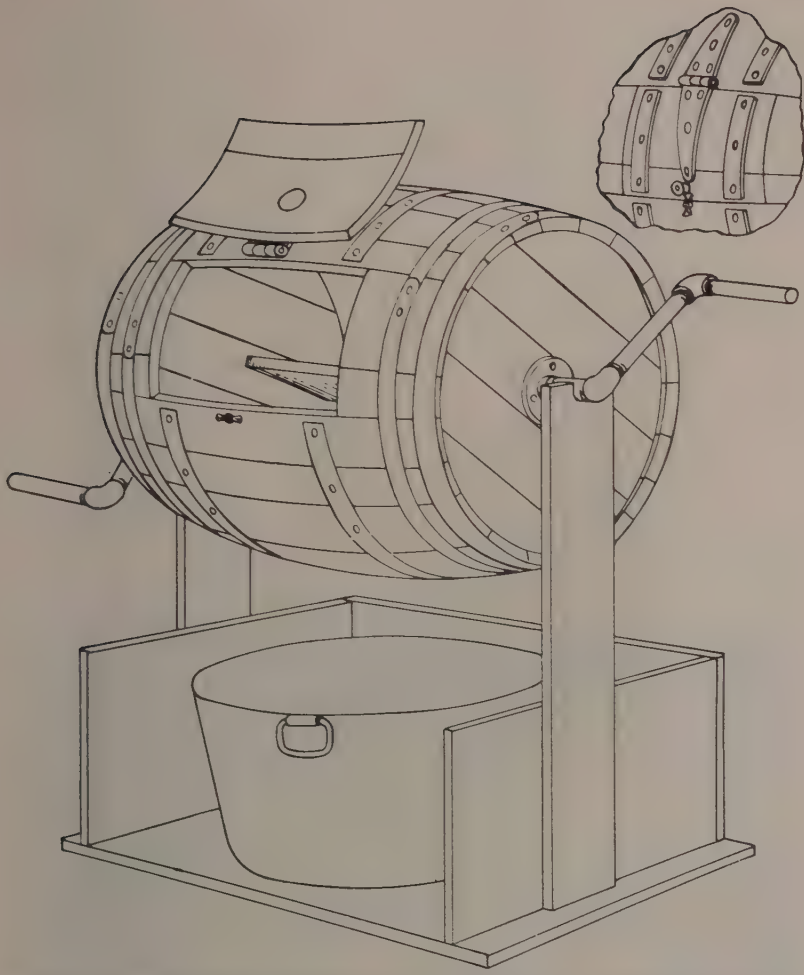

Figure 15.—Barrel treater, showing details of construction. (Designed by the late F. W. Oldenberg, University of Maryland.)

bushel to wheat, rye, barley, oats, and, with some restrictions, to sorghum at least 24 to 48 hours before seeding. Treated seed should be stored in a dry well-ventilated place. It should be emphasized that this material is poisonous, and treated seed should not be used for food or feed.

2. Agrox (6.7 percent phenyl mercury urea) has been tested for several years, and with few exceptions has been found effective for controlling certain smuts of wheat, oats, and barley. It is applied at one-half ounce per bushel. The directions on the container should be carefully followed.
3. Mergamma contains 1.93 percent phenyl mercury urea and 40 percent lindane (benzene hexachloride). The lindane is for the purpose of combating wireworms and false wireworms in the soil. From 1¾ to 2¼ ounces of Mergamma per acre is essential for wireworm control. Therefore, the recommended rate of applying Mergamma to the seed may

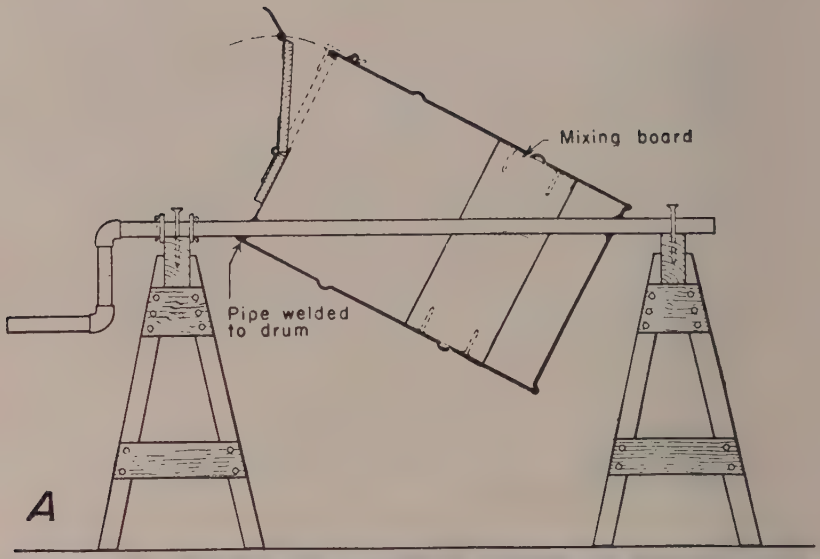

Figure 16.—Oil-drum treater, showing (*A*) details of construction and (*B*) manner of operation. (Designed by R. S. Kirby, Pennsylvania State College.)

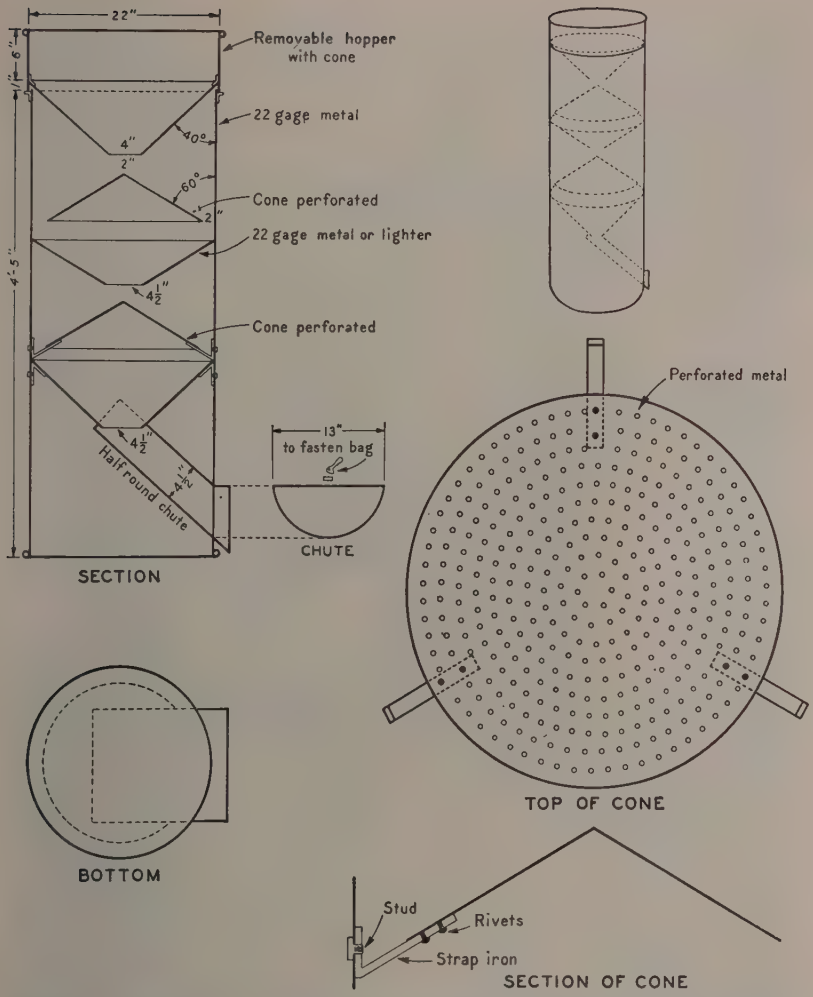

Figure 17.—Construction details of a gravity-type treater for applying volatile dusts to seed.

range from 1½ to 2½ ounces per bushel for seeding rates ranging from 2 down to 1¼ bushels per acre.

4. Anticarie (40 percent hexachlorobenzene) is designed only for bunt control in wheat and rye and is not recommended for any other cereal. It shows some promise of controlling bunt caused by soil infestation when applied to the soil in the furrow with the seed at the rate of about 100 pounds per acre. When applied to the seed at the rate of one-half ounce per bushel, it controls bunt caused by seed-borne spores but it does not act as a seed protectant against various fungi in the soil.
5. Tritisan (20 percent pentachloronitrobenzene) is an experimental material similar to Anticarie in that it is effective only for bunt control and not for other cereal smuts. It also shows some promise of being effective against soil-borne spores when applied to the soil in the drill row with the seed.

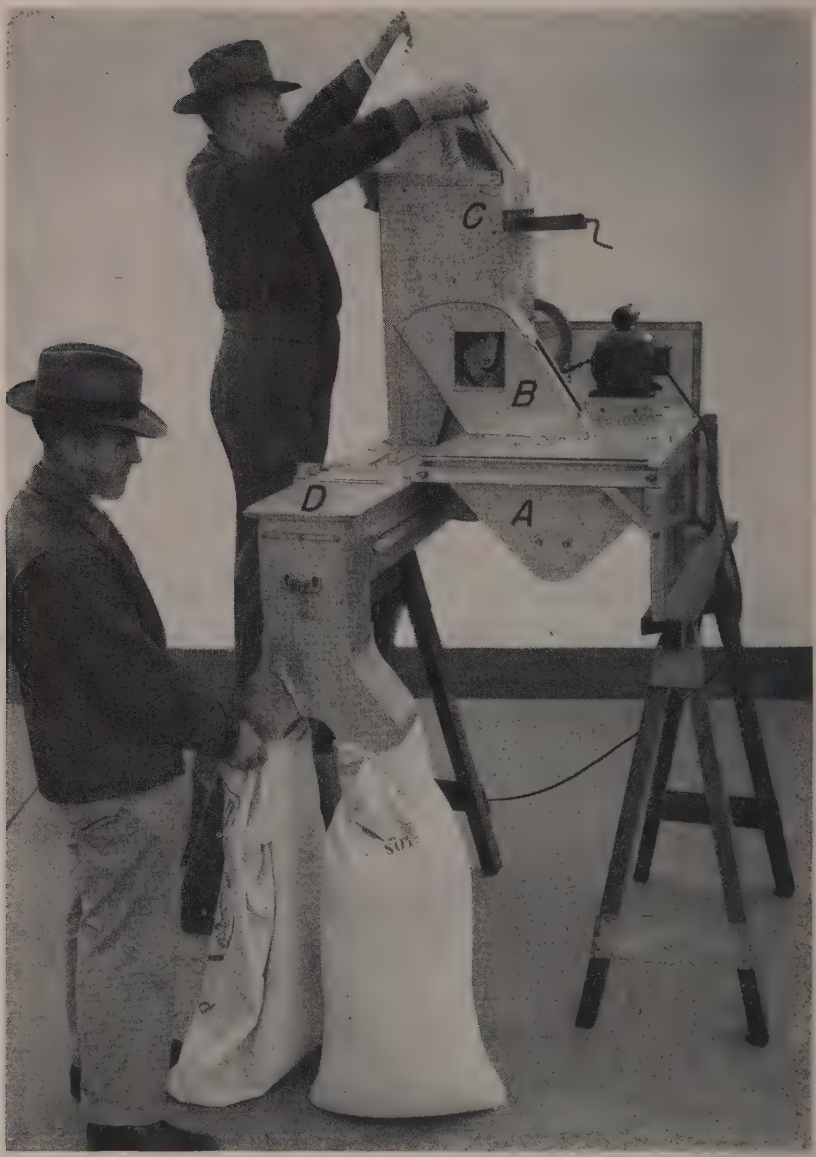

Figure 18.—Small-size slurry treater: *A*, Mixing tank; *B*, slurry cups on chain belt (enclosed); *C*, hopper with feed gate, which governs amount of seed receiving one cup of slurry; *D*, seed-mixing auger (enclosed) with bagging device at end. (In actual operation, grain usually is delivered to hopper by chute.)

6. Copper carbonate (50 percent copper) controls bunt in wheat and the kernel smuts[2] of sorghum when applied at the rate of 2 ounces per bushel.
7. Basic copper sulfate (50 percent copper) also controls bunt and the sorghum kernel smuts when applied at 2 ounces per bushel.
8. Arasan (50 percent thiram) controls bunt in wheat and the sorghum kernel smuts when applied at 2 ounces per bushel.

8b. Arasan SFX (75 percent thiram) is the form of Arasan intended for slurry application only. The directions on the container should be followed carefully.

9. Phygon (50 percent dichloronaphthoquinone), applied at 1 to 2 ounces per bushel, controls the sorghum kernel smuts and also stinking smut of wheat.
10. Spergon (98 percent chloranil) applied at 2 ounces per bushel controls bunt in wheat and the kernel smuts of sorghum.

Arasan, Phygon, and Spergon are excellent for treating seed corn to prevent seed rot and seedling blight, but they have no effect on corn smut. They may be applied to the seed in dust or slurry form.

Quick Wet Treatments

In the quick wet method of treatment, a relatively small amount of a concentrated, usually volatile, liquid fungicide is added to and thoroughly mixed with the seed. The dosage may range from one-half to 4 or more fluid ounces per bushel. This type of fungicide may be applied also in diluted form in a slurry treater, although it is not a true slurry treatment, as the seed when it dries is not coated with a dust residue.

11. Panogen (2.2 percent methyl mercury dicyan diamide) may be applied to wheat, barley, or oats at the rate of three-fourths fluid ounce per bushel in a special automatic Panogen treater constructed for that purpose. It may be applied also in a rotary mixer or, when properly diluted with water, in a slurry treater as previously mentioned. It controls all the smuts and other seedborne diseases of small grains that are amenable to control by chemical seed treatment. Like all mercury disinfectants, Panogen is poisonous and should be handled with care. Apply in a well-ventilated place, do not breathe in the fumes, and do not spill the chemical on the skin or clothing.
12. Setrete (7 percent phenyl mercury ammonium acetate) is similar to Panogen in that it can be applied either in concentrated form (at one-half fluid ounce per bushel) or in diluted form in a slurry treater. The latter is the generally recommended method of application. Complete directions for diluting and applying it are given on the container. It controls bunt in wheat, covered smut and nigra loose smut of barley, oat smuts, and the kernel smuts of sorghum.

Setrete is poisonous and the precautions mentioned for Panogen apply also to this material.

Gytrete, Pentrete, and Gallotox are the same as Setrete.

13. Vancide 51 contains 30 percent of the sodium salts of dimethyl dithiocarbamic acid and mercaptobenzothiazole. It is a relatively nonpoisonous liquid and is effective for controlling bunt in wheat and the kernel smuts in sorghum when applied at the rate of 4 ounces per bushel. It is nonvolatile and therefore is not recommended for treating seed of barley and oats.
14. MEMA, containing 11.2 percent beta-acetoxymercuriethyl methyl ether, is a water-miscible liquid material applicable to small grains as a preventive for certain smuts and other seedborne diseases. It may be applied in concentrated form as a quick wet treatment or it may be diluted and applied in a slurry treater.

Additional information on these and other fungicidal materials that may be offered for sale may be obtained by writing to the United States Department of Agriculture, or to your State agricultural experiment station.

[2] Volatile treatments are recommended for seeds with persistent glumes.

SCIENTIFIC NAMES OF CAUSAL FUNGI

Host and common name of disease	*Causal organism*
Wheat:	
Common bunt	*Tilletia caries* (DC.) Tul. *T. foetida* (Wallr.) Liro
Dwarf bunt	*T. brevifaciens* G. W. Fisch.
Loose smut	*Ustilago tritici* (Pers.) Rostr.
Flag smut	*Urocystis tritici* Koern.
Rye:	
Stalk smut	*U. occulta* (Wallr.) Rabh.
Barley:	
Covered smut	*Ustilago hordei* (Pers.) Lagh.
Nuda loose smut	*U. nuda* (Jens.) Rostr.
Nigra loose smut	*U. nigra* Tapke
Oats:	
Covered smut	*U. kolleri* Wille
Loose smut	*U. avenae* (Pers.) Rostr.
Sorghum:	
Covered kernel smut	*Sphacelotheca sorghi* (Lk.) Clint.
Loose kernel smut	*S. cruenta* (Kuehn) Potter
Loose smut (Johnson grass)	*S. holci* Jacks.
Head smut	*S. reiliana* (Kuehn) Clint.
Corn:	
Corn smut	*Ustilago maydis* (DC.) Cda.
Rice:	
Kernel smut	*Neovossia barclayana* Bref. (formerly *Tilletia horrida* Tak.)
Leaf smut	*Entyloma oryzae* H. & P. Syd.

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